National Aeronautics and Space Administration

NASA Case Study GSFC-1007C-1

Launching the *Vasa*

A lot rode on the men who were building the Swedish gunship *Vasa*, in 1626, and those who would sail her. It had been a calamitous decade for the Swedish navy. A dozen of Sweden's largest warships had been captured, wrecked, or scuttled; a violent storm in 1625 had destroyed 10 of those ships, prompting the imperious King Gustav II Adolf to order four new ones. Further losses had dramatically increased the king's impatience with his shipbuilders.

Recreation of the launching of the Vasa. Credit: Vasa Museum

Make it Longer!

The *Vasa* was first ordered as a small, traditional ship, but after numerous change orders from the king it was increased in both size and armament. A 111-foot keel was laid down, but almost immediately work stopped as the king learned that rival Denmark was building a larger ship with two gun decks, a new innovation. The *Vasa*'s keel was ordered to be increased to 135 feet, and the ship was now to include two enclosed gun decks.

No one in Sweden had ever built such a ship, and with the king making constant and ever-louder demands for both larger dimensions and faster delivery, there was no time for plans to be engineered. It was decided that scaling up the 111-foot keel, rather than laying a new, 135-foot keel, would save time.

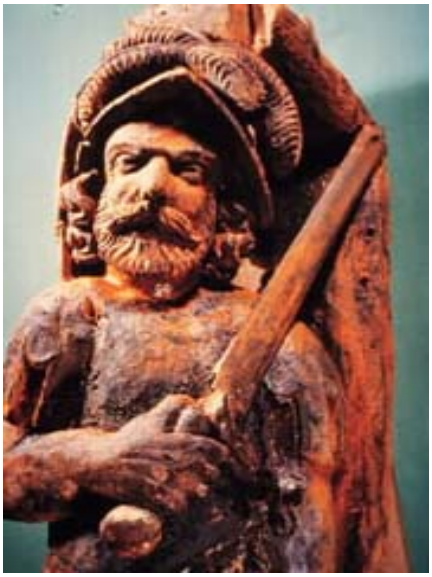
The shipbuilders added a fourth scarf to lengthen the keel, but the result was narrow in relation to its length and the draft very shallow for a ship of that size. A foot and a half was added to the beam, but because the keel was already laid it had to be added to the uppermost parts of the ship. This raised the center of gravity and contributed to the ship's instability. The shallow keel did not allow sufficient room for the ballast needed to stabilize a ship of that size, and the narrow beam required extra bracing timbers, further reducing room for the ballast.

More Guns!

Model of the Vasa's hull profile, showing shallow keel and two gun decks. Credit: Vasa Museum.

With a bigger ship, King Gustav demanded more—and bigger—guns, insisting on 64 24-pounders, half on each deck, plus numerous smaller ones. Though it was built for 12-pounders, the upper deck now had to carry the added weight of 24-pounders, which further raised the center of gravity. In the end, the rushed schedule allowed for 48 24-pounders.

Adding to the top-heavy condition: hundreds of ornate, gilded, and painted carvings made of heavy oak, also ordered by the king. Meant to outshine the Danish ship, no cost was spared, and the *Vasa* became the most expensive ship of its time.



Recovered oak carving. Credit: Vasa Museum

Management Change

In 1626, the head shipbuilder became very ill. While bed-ridden, he had to share his duties with two others, which led to confusion over project management. Division of responsibility and communication was weak, exacerbated by the king's impatience and ever-changing demands and resulting in further delays. With the largest workforce in Sweden's history essentially running amok, the shipbuilder died in 1627.

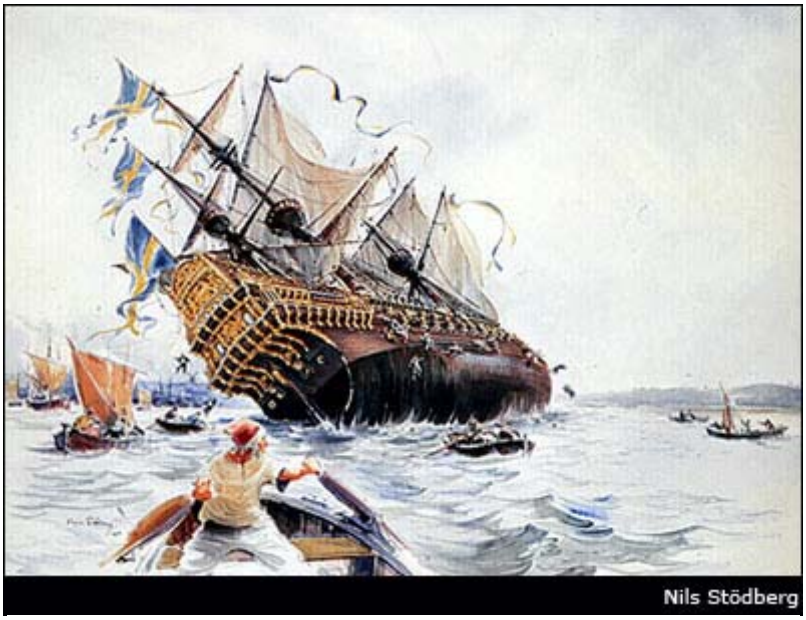
At the time, there were no standardized calculations for center of gravity, heeling characteristics, and stability factors. Ship captains learned their ships' characteristics by trial-and-error. Even naval experts believed that the higher and more impressive a ship, and the more guns it carried, the more indestructible the ship would be.

Launch Readiness Test

Finally, all that remained was a test of the *Vasa*'s seaworthiness. Called a "lurch" test, the ship's captain and the king's admiral had a skeleton crew of 30 men run from gunwale to gunwale amidships on a windless day in calm harbor waters. After three such sprints, the test was stopped because the ship was rocking so violently that the captain feared it would capsize. The shipbuilders were not present nor were they informed of the test results. No action was taken after the alarming results because the only known corrective course was 'more ballast,' which was not a viable option. Already loaded with 120 tons of ballast, there was no room for more. Even if there had been more room, the additional weight would have put the lower deck gun portals near or below the waterline. As it stood, those ports were only 3½ feet above the waterline.

The Launch

It is July 25, 1628. You are the king's admiral. You are under orders to launch today or suffer severe personal and professional consequences. You are being held responsible for the careers of the shipbuilder and shipwright, and the lives of the ship's captain and his 150-man crew. You are also responsible for the image of an expansionist Sweden and its main weapon, the Swedish Navy, now severely crippled by losses during wartime.



Credit: Vasa Museum

Reluctant, but obedient, and unwilling to stall any longer, on August 10, 1628, you order the ship to be pulled away from the wharf. A few sails are raised just as a light breeze picks up to fill the sails. The breeze fills the ship's sails and lifts spirits. The *Vasa* sails about 1,000 yards, heels over, and sinks in view of the entire spectator crowd. Fifty souls are lost along with the entire ship. What went wrong? What would you do differently next time? Fortunately, you have access to some of the risk analyses (see **Exhibit 1**) done during the project to look for clues and lessons learned.

Crunch Time

King Gustav was in Poland and out of communication, though he had ordered that the ship be launched by July 25 and "if not, those responsible would be subject to His Majesty's disgrace." Neither the shipwright nor the shipbuilder had been present for the lurch test, and no one had suggested any ideas for increasing the *Vasa*'s stability. You know that upon the king's return there will be a royal board of

inquiry, and you will have some tough questions to answer. You start thinking about them now to prepare yourself for what lies ahead. You decide to call together a small group of your trusted advisors and together you mull over these questions:

1. Who is responsible for this catastrophe?
2. Were there any inappropriate risks that should not have been taken? How can these be identified and mitigated on future shipbuilding initiatives?
3. How can unknown areas be addressed beyond relying on the shipbuilder's personal expertise? How do we advance into areas that are unknown?
4. How could the communications between the king, the shipbuilders, and the navy command be improved for the contracting, building, and delivery of future warships in a timely, on-schedule, and within-budget manner?
5. What is the most important thing we can do to prevent this type of disaster from happening again?

Resources

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Exhibit 1

Selected VASA Project Risk-Management Documents

Risk Title: Complexity of Interprogram Management Structure				**Owner:** Shipbuilder
Risk Statement: Given the complexity of the interprogram management structure in the Swedish navy and the historic cultural differences between civilian, naval, and royal offices, there is a possibility that integration of the *Vasa* project will be negatively impacted.				
Likelihood: 2	**Safety:** 1	**Performance**: 2	**Schedule:** 2	**Cost:** 2
Context: There is the built-in complexity of the *Vasa* organization and the work packages-making system-interfaces complex. This is most apparent between the shipbuilding team and the king's court. Requirements, design, and implementation processes, procedures, and formal office-to-office agreements have not been documented. There are multiple approaches from different quarters in solving a common technical risk. The resulting impact to the *Vasa* project is in not meeting the schedule and inefficient implementation due to cultural differences and drivers with foci that are different from that of the mission.				
Status: Awaiting word from the king on design changes (July 1626). Death of Master Shipwright Hybertsson increases risk (Spring 1627)?				
Mitigation Plan: The *Vasa* project will watch this risk to see if it becomes an issue.			**Fallback Plan:** Install more carvings of Norse Gods on the ship.	

Risk Title: Timely Availability of Skills/Skills Mix and Cultural Changes				**Owner:** Shipbuilder
Risk Statement: Given the current skill availability, mix, and culture, there is a possibility that we may not be able to execute a new ship-building project in a timely manner.				
Likelihood: 4	**Safety:** 0	**Performance:** 0	**Schedule:** 4	**Cost:** 0
Context: The combination of the two different-sized ships being built simultaneously, the ongoing war (affordability questions), the mix of older shipbuilders and new warfare strategies is pushing the project outside of known experience bases in size, weight, and operations' designs.				
Status: Interviewing key stakeholders for better understanding (July 1626). Schedule slips are unavoidable due to changing requirements (Spring 1627).				
Mitigation Plan: Research; interview the key stakeholders to identify skills gaps and cultural differences.			**Fallback Plan:** Install more carvings of Norse Gods on the ship.	

Exhibit 1 (continued)

Risk Title: Synchronization of Core Ship and the Gun Deck Architectures				**Owner:** Shipbuilder
Risk Statement: Given the existing challenges the *Vasa* project is addressing and the instability in the *Vasa* configuration, there is a possibility that the gun deck (war-fighting capability) project will not be able to maintain synchronized design analysis cycles leading up to an agreed architecture.				
Likelihood: 3	**Safety:** 0	**Performance:** 3	**Schedule:** 5	**Cost:** 4
Context: Both the ship core architecture (keel, beam, tonnage, and ballast) and the gun deck (armaments, configuration, gun mix, and mass) have and continue to undergo revisions and requirements changes. This instability of requirements makes it difficult to synchronize the architectures and will likely require rework, and/or compromises that could affect the success of the mission. For example: The armaments command is requiring all 24-pounders (both gun decks) to standardize on gun fixtures and ammunition for efficient use in battle.				
Status: Upper gun deck ports already installed are too small for 24-pounders (Fall 1627). Schedule interchange meeting to compromise on upper deck guns.				
Mitigation Plan: Attempt to synchronize the design and load cycles of both ship and weapons.			**Fallback Plan:** Install more carvings of Norse Gods on the ship.	

Risk Title: *Vasa* Vehicle Test Environment Limitations				**Owner:** Shipbuilder
Risk Statement: Given that the current *Vasa* design concept (modified) has high stability-test levels (load testing) and the adaptation of existing or modified structures (timbers) and components (guns, decorative art) is intended for use in many *Vasa* applications, there is a possibility that the *Vasa* project may incur schedule slips and increased cost due to subsystem failures requiring more system-level test cycles to achieve qualification.				
Likelihood: 4	**Safety:** 1	**Performance:** 3	**Schedule:** 5	**Cost:** 3
Context: Historically some ship designs have failed (sunk due to instability) and required some redesign. Critical stability tests are driven by core ship-design issues. Current schedule analysis indicates significant overlap between subsystem qualifications and completion of seaworthiness build, assembly, and test cycles.				
Status: *Vasa* project is made the highest priority by order of the king (November 1625). Admiral Fleming to conduct a prelaunch lurch test with 30 sailors (July 1627).				
Mitigation Plan: Results of lurch test to be analyzed for adjusting ballast before launch.			**Fallback Plan:** Install more carvings of Norse Gods on the ship.	

Exhibit 1 (continued)

Vasa Specifications

	**Original Design Plan**	**After 1st Major Requirements Change**	**As Launched**
Start date	January 1625		
Launch date	1626	1627	August, 10, 1628
Tonnage	As for smaller ship	Added upper deck, guns and ship length	ca 1,200 ton (2,650,000 lb) as estimated from excavation
Length	135 feet (ft) for the large ship; 108 ft as a small ship; 111 ft as laid down	120 as called for by the King's revisions	135 ft as extended by a fourth scarf joint extension timber
Beam	34 ft for large ship; laid as specs for smaller ship (20 ft)	24 ft as called for by the king's revisions	35 ft then up to 38.4 ft with (above water) widening timbers
Ballast	Enough by builder's judgment	Whatever will fit in the ballast area	120 tons (determined by excavation)
Draft	As for small ship	As for large ship	4.8 meters (15.7 ft) after being weighed down with maximum ballast
Propulsion			10 sails; total area of 1,275 meters^2
Crew	Not known, but less with the fewer armaments	145 sailors plus 300 soldiers	150 persons including women and children (probably relatives of the crew). No soldiers were aboard.
Armament	One gun deck with ports for 32 guns; 24 pounders–32	Two gun decks with up to 78 guns including: 24 pounders–36; 12 pounders–24; 48 mortars–8; small guns–10	Two gun decks with 64 guns, including: 24-pounders–48; 3-pounders–8; 1-pounders–2; mortars–6
Cost	Contract for four ships: two small and two large	No limit for the king's honor was at stake.	200 Swedish rex; 5% of Sweden's gross national product (billions and billions in today's value)

Source: Wikipedia.com; corroborated by other sources.